

**ERRATUM**

**SPECIFICATION No. 976,573**

Page 1, Heading, *delete* "Patent of Addition  
to No. 829,574 dated Oct 3, 1956"

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# PATENT SPECIFICATION

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## COMPLETE SPECIFICATION

### Improvements in and relating to Metal Plating

We, UNION CARBIDE CORPORATION, of 270 Park Avenue, New York, State of New York, United States of America, a Corporation organised under the laws of the State of New York, United States of America, (Assignee of WALTER HAFNER and ERNST OTTO FISCHER), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a metal plating process. More particularly the invention relates to a process for utilizing volatile bis-(arene)metal compounds as metal plating agents.

Heretofore several processes have been suggested for metal plating by means of volatile metal-containing compounds. In general, these processes have been subject to contamination of the metal plate due to oxide or carbide formation or the occlusion of undesirable solid materials in the metal plate. The nature of this contamination is discussed in more detail hereinbelow.

In copending application No. 30087/55 Serial No. 829574 there is described a process for the production of bis(arene)metal compounds by the reaction of an anhydrous transition element salt, preferably a transition element halide, with an aromatic compound having at least one isolated benzene ring system or with an aryl-substituted benzene in the presence of an anhydrous aluminium halide and a reducing agent.

According to the present invention, a process for depositing a substantially pure metal plate on a platable solid substrate comprises contacting, by means of an inert oxygen-free carrier gas, a bis(arene)metal compound represented by the formula  $(Ar)_2M$ , wherein each Ar is an aromatic hydrocarbon containing an isolated benzene ring or an aryl-sub-

stituted benzene and M is vanadium, niobium, tantalum, chromium, molybdenum or tungsten, with platable solid substrate at a temperature above the decomposition temperature of said bis(arene)metal compound while excluding oxygen and reactive oxygen-containing substances.

The bis(arene)metal compounds useful in the process of this invention are those wherein the arene organic groups are aromatic hydrocarbons containing an isolated benzene ring or are aryl-substituted benzenes. The nature of these arene organic groups is discussed in more detail hereinbelow.

The compounds useful in this invention may, from the point of view of their organic part, be characterized as addition compounds in contrast to organo-metallic substitution compounds wherein a hydrogen or other substituent in the organic nucleus is substituted or removed in formation of an organo-metallic compound. Thus the compounds used in the present invention are to be distinguished from those formed by the chemical bonding of a cyclopentadienyl radical with an element (Fischer and Pfab, Zeit. fur Naturforschung, 7b, page 377, (1952)), and phenyl mercury compounds e.g., phenyl mercuric acetate (U.S. Patent 2,502,222). Formation of such substitution compounds involves elimination of one hydrogen on the cyclopentadiene or benzene nucleus. In the case of the compounds of the present invention the chemical union of the transition element with the aromatic compound does not involve elimination of hydrogen or any other substituent on the benzene nucleus. It may, therefore, be regarded as an addition produce of the transition element with the aromatic organic molecule. Such addition of an aromatic compound to a transition element is an unexpected characteristic of aromatic compounds.

As employed in this application the term "isolated benzene ring system" means a benzene carbon ring *per se* and as contained in a fused ring compound containing a benzene carbon ring wherein, by the Kekule formula-  
 5 tion, any double bond in a ring fused to such benzene carbon ring is removed from the benzene ring carbon atom nearest to its by at least two carbon atoms of the ring fused to  
 10 the benzene ring, and a compound having one or more aliphatic substituents on a benzene ring wherein any double bond external to the carbon ring is removed from the benzene ring carbon atom nearest to it by at  
 15 least two carbon atoms external to such benzene carbon ring. Thus, benzene, aliphatic substituted benzenes, including alkyl substituted benzenes and alkenyl substituted  
 20 benzenes in which double bonds external to the benzene ring are separated therefrom by at least two carbon atoms, indane, tetrahydronaphthalene, 9,10 - dihydroanthracene, 9,10 - dihydrophenanthrene and allyl benzene  
 25 are examples of aromatic compounds containing an isolated benzene ring system. By contrast naphthalene, indene, anthracene, phenanthrene and styrene are examples of aromatic compounds which do not contain an isolated benzene ring.  
 30 This difference in the isolated and not isolated benzene ring systems may be explained in terms of the characteristics of the two types of compounds with respect to their aromatic nature. The fusion of a benzene  
 35 ring to another aromatic ring in conjugated relation thereto, or linkage of a ring carbon atom of a benzene ring to an unsaturated aliphatic radical wherein the ring carbon is linked to an aliphatic carbon atom which in  
 40 turn is linked by a double bond to another aliphatic carbon atom, may be considered as orienting the double bonds in the benzene ring, thus producing a ring structure of less reactivity than is characteristic of an isolated  
 45 benzene ring and rendering the electrons in the double bonds of the benzene ring unavailable for reaction with the transition element halides. This essential characteristic may also be explained upon energy considera-  
 50 tions. The fusion of an aromatic ring to the benzene ring in conjugated relation and the inclusion of an unsaturated aliphatic radical on the benzene ring with the unsaturation in the aliphatic constituent being in conjugated  
 55 relation with double bonds in the benzene ring may be considered as decreasing the energy and concomitantly increasing the stability of the ring to such a point that the compounds useful in this invention cannot  
 60 be prepared.

A class of arene hydrocarbons which do not contain an isolated benzene ring, namely aryl-substituted benzenes, also form organo-metallic compounds useful in the present invention. Examples of such aryl-substituted

benzenes are polyphenyls, alkyl-substituted polyphenyls such as *p* - isopropylidiphenyl and *p* - *p'* - dimethyldiphenyl, phenylanthracene and phenylphenanthrene.

The compounds useful in the process of this invention may be represented by the formula:



wherein Ar represents an organic hydrocarbon compound which may be an aromatic hydrocarbon containing an isolated benzene ring or an aryl-substituted benzene, the organic compound being bound to a transition element M, and M is vanadium, niobium, tantalum, chromium, molybdenum or tungsten.

Moreover the metal complexes may have mixed Ar substituents and consequently may have the formula:



wherein the symbols are the same as above except that Ar' is different from Ar.

The exact nature of the bond between the Ar portion of the molecule and the transition element is unknown; however, it is known that the isolated benzene ring or the benzene ring of the aryl-substituted benzene is complexed to the transition element.

Our aforementioned copending application describes the method for the production of bis(arene)metal compounds suitable for use in the present invention. In particular, detailed examples are given showing the preparation of bis(benzene)chromium, bis(benzene)molybdenum, bis(tetrahydronaphthalene)chromium, bis(benzene)vanadium, bis(toluene)chromium, bis(mesitylene)chromium, bis(hexamethylbenzene)chromium, bis(ortho-xylene)chromium, bis(meta-xylene)chromium, bis(para-xylene)chromium, bis(benzene)tungsten, (benzene) (tetrahydronaphthalene)chromium, and bis(diphenyl)chromium. Other compounds useful in this invention and included in the formula  $(Ar)_2M$ , such as bis(benzene)niobium, bis(benzene)tantalum, bis(diphenyl)molybdenum and bis(cumene)chromium are also prepared by this process.

Broadly stated the process of the present invention comprises contacting an uncharged, volatile bis(arene)metal compound with a platable solid substrate at a temperature above the decomposition temperature of the bis(arene)metal compound. In general this temperature will be above 150°C. Temperatures considerably above the decomposition temperature of the diarene metal compound may be used and temperatures up to 600°C. are operable. The upper limit of operable temperatures for the process of this invention is determined by the properties of the arene organic group. If the operating temperature is too high, the arene organic group will decompose to give carbon or polymerizable hydrocarbons such as ethylene and acetylene which may cause contamination of

the metal plating. Thus, the lower operable temperature for the process is set by the decomposition temperature of the bis(arene)-metal compound and the upper operable temperature limit is determined by the decomposition (cracking) temperature of the arene organic part.

The process of this invention must be carried out in substantially oxygen free surroundings. Oxygen may react with the diarene organic compound or other metal plate itself to form metal oxides which contaminate the metal plate. Also, oxygen-containing substances which will react with the plating compound or metal plate at the operating temperature must also be substantially excluded.

As pointed out hereinabove the process of the present invention applies to the bis-(arene)metal compounds of vanadium, niobium, tantalum, chromium, molybdenum and tungsten wherein the arene group is an aromatic hydrocarbon compound containing an isolated benzene ring, or an aryl-substituted benzene. There are the transition elements which form neutral diarene metal compounds as opposed to those transition metal elements which form only salt-like compounds containing a diarene metal cation, for example, dimesitylene iron dibromide. The decomposition of the latter compounds may give a metal plate contaminated by occlusion of or reaction with elements or moieties present in the anionic portion of the compound.

Any platable solid substrate which is thermally stable at the plating temperature may be used in the process of the present invention. Platable substrates include glass, glass cloth, ceramics, plastics such as Nylon and Bakelite (a Registered Trade Mark), and a variety of metals such as copper, aluminum, stainless steel and silver.

The process of the present invention, which employs volatile bis(arene)metal compounds, is to be distinguished from processes employing other volatile metal-containing compounds. The compounds useful in the process of the present invention have the unique and important property of decomposing to give a substantially pure metal and a stable, volatile organic compound. It is the stable nature of the organic compound which makes possible the substantially pure and uncontaminated metal plates obtained by the process of this invention. In general, the volatile metal-containing compounds heretofore known contain some element or part which can cause contamination of the metal plate. For example, metal carbonyls such as chromium hexacarbonyl are volatile. When the metal carbonyl is decomposed, however, carbon and oxygen derived from the carbon monoxide which is released may react with the metal plate to form metal oxides or metal carbides. As another example, dicyclopenta-

dienyl compounds such as dicyclopentadienyl iron are volatile. However, the cyclopentadienyl group which results from the decomposition of such compounds is not a stable entity. The cyclopentadienyl group polymerizes readily to form solid residues or decomposes to give carbon and polymerizable hydrocarbons. The resulting carbon and organic copolymers cause contamination of the metal plate.

The contact between the bis(arene)metal compounds and the platable substrate is brought about by passing the vapors of the diarene metal compound over the substrate by means of a carrier gas which is oxygen-free and which does not otherwise react with the metal plate or the diarene metal compound. Examples of suitable carrier gases are argon, nitrogen, helium and hydrogen. Atmospheric pressure is most convenient but higher or lower pressures may be used if desired. The contacting of the diarene metal compound with the platable substrate may be continued until a plate of the desired thickness is obtained.

The organo-metallic compounds of this invention may vary in heat stability but they may all be decomposed by the employment of temperatures in excess of 400°C. Such thermal decomposition of the compounds results in formation of metallic mirrors comprising a coating or film of the particular transition element. Such metallic coatings and films exhibit desirable and useful electrical conductance properties, furnish corrosion protection when applied to corrodible base materials and result also in striking decorative effects. Compounds of this invention may thus be deposited on glass, glass cloth, resin and other insulating substrates, and the resulting metal-coated material may be employed as strip conductors and resistors for electrical purposes. The metals may be deposited by thermal decomposition in desired portions of the substrate to provide the so-called printed electrical circuits. Similarly the metals may be plated on metal substrates to enhance corrosion resistance and on glass cloth or asbestos to provide decorative metallic surfaces and designs thereon.

In a preferred embodiment of the present invention bis(arene)metal compounds are used in which the arene organic group is benzene or a lower alkyl-substituted benzene. Such preferred compounds may be represented by the formulae  $R_2Cr$ ,  $R_2Mo$ ,  $R_2W$ ,  $R_2V$ ,  $R_2Nb$  and  $R_2Ta$  wherein R is benzene or a lower alkyl-substituted benzene. Examples of the preferred compounds are bis(benzene)vanadium, bis(toluenes)vanadium, bis(benzene)chromium, bis(toluenes)chromium, bis(cumenes)chromium, bis(mesitylenes)chromium, bis(benzene)molybdenum, bis(toluenes)molybdenum, bis(mesitylenes)molyb-

denum, bis(cumene)molybdenum, bis(benzene)tungsten and bis(toluene)tungsten.

A particularly useful mixture of compounds for chromium plating according to the process of this invention is a mixture of bis(xylene)chromium compounds. The pure compounds are all solids at room temperature, bis(ortho-xylene)chromium melting at 142°C., bis(meta-xylene)chromium melting at 34 to 36°C., and bis(para-xylene)chromium melting at 110°C. However, a mixture of these three isomers is a liquid at room temperature.

A preferred temperature for the process of this invention is a temperature 75°C. above the decomposition temperature of the bis-(arene)metal compound. This preferred temperature will vary from 200°C. for bis-(arene)molybdenum compounds up to 350 to 400°C. for bis(arene)chromium and bis-(arene)vanadium compounds.

When the substrate to be plated has relatively low thermal stability, another preferred embodiment of this invention involves the use of bis(polyphenyl)metal compounds which may be represented by the formula  $D_2M$  wherein D is diphenyl or a lower alkyl-substituted diphenyl and M is vanadium, niobium, tantalum, chromium, molybdenum or tungsten. Examples of such compounds are bis(diphenyl)chromium, bis(diphenyl)molybdenum, bis(diphenyl)tungsten, bis(diphenyl)vanadium, bis(p-isopropyldiphenyl)chromium, and bis(p,p'-dimethyldiphenyl)molybdenum. In general, such bis-(diphenyl)metal compounds and bis(lower alkyl-substituted diphenyl)metal compounds decompose at lower temperatures than do the bis(benzene)metal compounds or bis(alkyl-substituted benzene)metal compounds. Thus, the use of compounds such as bis(diphenyl)chromium is particularly advantageous when the substrate has relatively low thermal stability and the plating process must be carried out at the lowest possible temperatures.

The following examples are illustrative of the plating process of the present invention.

#### EXAMPLE I

A three foot high length of Pyrex (a Registered Trade Mark) glass tubing 25 millimeters in diameter was fitted with an inlet tube and an exit tube and argon was passed through the system. In the upstream end of the 25 millimeter tube was placed a quartz boat containing one gram of bis(toluene)molybdenum. The downstream end of the tube was enclosed in a tube furnace and heated to 250°C. The portion of the tube near the quartz boat was then heated to 100°C. to vaporize the bis(toluene)molybdenum into the argon stream. As the stream of bis(toluene)molybdenum in argon entered the zone heated to 250°C, rapid decomposition occurred and a shiny molyb-

denum metal plate formed on the inner walls of the glass tubing.

#### EXAMPLE II

Bis(diphenyl)molybdenum is used to deposit a molybdenum plate on glass according to the procedure of Example I except that a temperature of only 200°C. is required to bring about rapid decomposition of the plating compound.

#### EXAMPLE III

A three-foot section of Pyrex (a Registered Trade Mark) glass tubing one inch in diameter was fitted with an inlet tube and exit tube. In the upstream end of the one-inch tube was placed a porcelain boat containing one gram of bis(benzene)chromium. In the downstream end was placed a graphite rod 2 inches long and 3/4 inches in diameter. The downstream end was enclosed in a tube furnace and heated for one hour at 400°C. Then the porcelain boat was removed into the heated zone. The bis(benzene)chromium sublimed into the argon stream and decomposed on the surface of the boat and on the graphite rod. Both the porcelain and graphite surfaces were coated with a shiny chromium metal plate.

#### EXAMPLE IV

Following the procedure of Example III, bis(cumene)chromium is used to deposit a chromium metal plate on porcelain and graphite.

#### WHAT WE CLAIM IS:—

1. A process for depositing a substantially pure metal plate on a platable solid substrate which comprises contacting by means of an inert oxygen-free carrier gas a bis-(arene) metal compound represented by the formula  $(Ar)_2M$ , wherein each Ar is an aromatic hydrocarbon containing an isolated benzene ring or an aryl-substituted benzene and M is vanadium, niobium, tantalum, chromium, molybdenum or tungsten, with a platable solid substrate at a temperature above the decomposition temperature of said bis(arene) metal compound while excluding oxygen and reactive oxygen-containing substances.
2. A process as claimed in Claim 1, in which vapors of the bis(arene) metal compound are contacted with the substrate under atmospheric pressure.
3. A process as claimed in Claim 1 or 2, in which the inert carrier gas is argon, nitrogen, helium or hydrogen.
4. A process as claimed in any of the preceding claims, in which the operating temperature is 75°C. higher than the decomposition temperature of the bis(arene) metal compound.
5. A process as claimed in any of the pre-

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ceding claims, in which the bis(arene)metal compound is a bis(arene)chromium compound.

5 6. A process as claimed in claim 5, in which the bis(arene)chromium compound is bis(cumene)chromium, bis(benzene)chromium or a mixture comprising bis(ortho-xylene)chromium, bis(meta-xylene)chromium and bis(para-xylene)chromium.

10 7. A process as claimed in any of claims 1 to 4, in which the bis(arene)metal compound is a bis(arene)molybdenum compound.

15 8. A process as claimed in claim 7, in which the bis(arene)molybdenum compound is bis(toluene)molybdenum or bis(diphenyl)molybdenum.

20 9. A process as claimed in any of claims 1 to 4, in which the bis(arene)metal compound is a bis(arene)vanadium compound.

10. A process as claimed in claim 9, in

which the bis(arene)metal compound is bis(toluene)vanadium.

11. A process as claimed in any of claims 1 to 4, in which the bis(arene)metal compound is a bis(arene)tungsten compound.

12. A process as claimed in claim 11, in which the bis(arene)tungsten compound is bis(benzene)tungsten.

13. A process for depositing a substantially pure metal plate on a platable solid substrate substantially as hereinbefore described with reference to and as illustrated in any of the Examples.

14. A substantially pure metal plate whenever produced by the process described in any of the preceding claims.

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